CHAPTER V

Transportation Network Model

TRANSPORTATION MODELING

This chapter documents the development of a transportation model for the City of Rifle. Besides documenting the development effort, it also presents an explanation of the calibrated network to be used in the overall project, looking into the future.

The analysis of the highway transportation system and alternatives for improving transportation facilities in Rifle is based on the use of a transportation planning model. The model is a computerized representation of the transportation system. This computerized model is useful for comparing the impacts of various growth assumptions and for evaluating alternative transportation improvement programs. It would also be possible to use growth factors based on the recent trends. However, a model allows the use of better projections of growth within the region, accounting for subarea-specific development.

Transportation models, by definition, are representations of travel choices made by individuals across a geographic area, impacting physical structures such as roads, bridges, parking areas, and intersections. Each model should rely on sound behavioral theory of how individuals make travel choices, often referred to as "user equilibrium." The structure of choice sequences suggested by the model and the variables used in the model should reflect a logical process of decision-making that provides a basis for judging the "reasonableness" of model estimation results.

The travel choices of individuals, as most commonly practiced in the United States, are represented by what is referred to as the "four-step process." These four steps are supposed to represent the thought processes of the individual. The individual makes four travel decisions as follows: the decision that a trip is necessary to fulfill some need or purpose (generation), the decision where that need/purpose is best fulfilled (distribution), the decision of which means is best to get there (mode choice), and the decision of which route to take (trip assignment).

Geographic patterns are represented by data considered to be at the heart of individual travel decisions: where people live, where people work, and where people recreate, shop, or otherwise interact. The specific data used in this project are discussed more fully in the sections below.

The physical structures of travel are represented through a combination of links (paths) and nodes (intersections or transfer points). Zone centroids are special types of nodes associated with both the data mentioned above and the origins and destinations of an individual's trips. The links typically have a travel time associated with them, either explicitly given or inferred from speed and distance information.

Networks

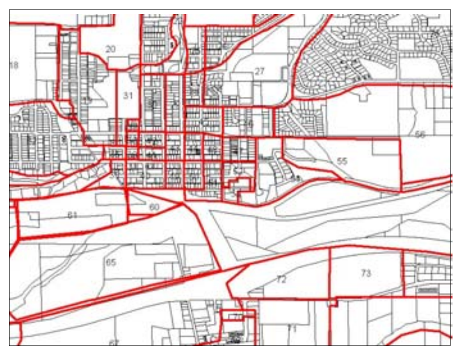
At its simplest level, a network is nothing more than a representation of the highway system. As such, it can be analyzed by computer in order to study the effects of certain variables, to plan changes in an existing highway system, or to forecast new patterns if the system is upgraded or altered. The term "transportation network" is itself quite flexible; it may be applied to a regional highway system, to a sub-regional segment such as a traffic corridor, or to a transportation sub-area such as a city's central business district. The flexibility of the concept, plus the capabilities of the modern computer, make transportation networks a significant part of many transportation planning activities.

The detail represented in a specific network will vary from city to city. More often than not, the level of detail will depend upon the purpose of the analyses and upon the availability of resources for coding and processing network information. For example, regional planning networks might only represent the higher classes of facilities (freeways, expressways, and other arterials); for corridor analyses, collectors and some local roads could also be included. Networks should be developed with the traffic analysis zones (TAZs) used for coding information and then generating and distributing trips from zone to zone using computer software.

Coding a network requires decisions regarding level of detail, assembly of information, and conversion to the format required to create the link and node data files used by the specified computer software used for forecasting. Prior to making any decision about the level of detail that will be assembled and coded, the user may want to first answer questions about how the network will be used. The first step in coding the Rifle network for travel demand forecasting is establishing the TAZs. The following text discusses traffic analysis zones used in the Rifle travel demand model.

TRAFFIC ANALYSIS ZONES

Introduction



Traffic Analysis Zones are used to represent areas of relatively homogeneous land use and demographic characteristics. Because it would be impossible to determine each individual's travel characteristics, demographic and development data are used to establish travel relationships. These data are used on an aggregate level for small geographic areas. In selecting TAZs for use in the modeling process, an effort is made to determine areas with homogeneous travel characteristics. The number and size of TAZs must achieve a balance between homogeneity within the zones and a reasonable number of zones for the analysis.

There area several basic principles which are used in selecting the boundaries of TAZs. The road network to be modeled is a prime consideration. Travel internal to a TAZ is not represented in the network model, so zones must be small enough to identify travel on important corridors. Geographic features frequently serve as natural boundaries of TAZs, reflecting a natural barrier to travel. In areas of greater interest, the TAZs should be smaller so that the travel volumes are reflected on the network links.

The above principles establish guidelines for selecting TAZ boundaries. As may be expected, it is not always possible to satisfy each principle for every TAZ when modeling an actual transportation network.

Rifle Traffic Analysis Zones

Figures V-1 and V-2 illustrate the TAZs established by the LSC Team for use in the Rifle Model. These zones are based on consideration of land use, demographics, and the Rifle street system. Census Blocks released for 2000 were used as a starting point for the formation of the zones. These blocks included population and household information for Rifle. The Rifle Comprehensive Plan, zoning maps, and aerial photos were used to refine the boundaries of the TAZs. Similar land use characteristics were grouped to provide as much homogeneity as possible within each TAZ. However, each TAZ is not perfectly homogeneous and may contain land use variations within a specific zone. For modeling purposes, minor internal variations in land use within the TAZ do not affect the reliability of the model. The system of mesas in Rifle forms natural barriers to travel and are logical boundaries for the TAZs.

The central business district of Rifle was divided into smaller TAZs than the residential areas. This reflects the desire to create a model which maintains homogeneity of land use, similar levels of trip generation, and more detailed analysis of the street system within the commercial area. Several zones have been identified as special generators. Special generators represent relatively unique facilities which do not have trip generation patterns that are the same as the rest of the community. The Grand River Hospital District and the local schools have been identified as special generators and were given special consideration within the model.

Figure V-1
Rifle Traffic Analysis Zones

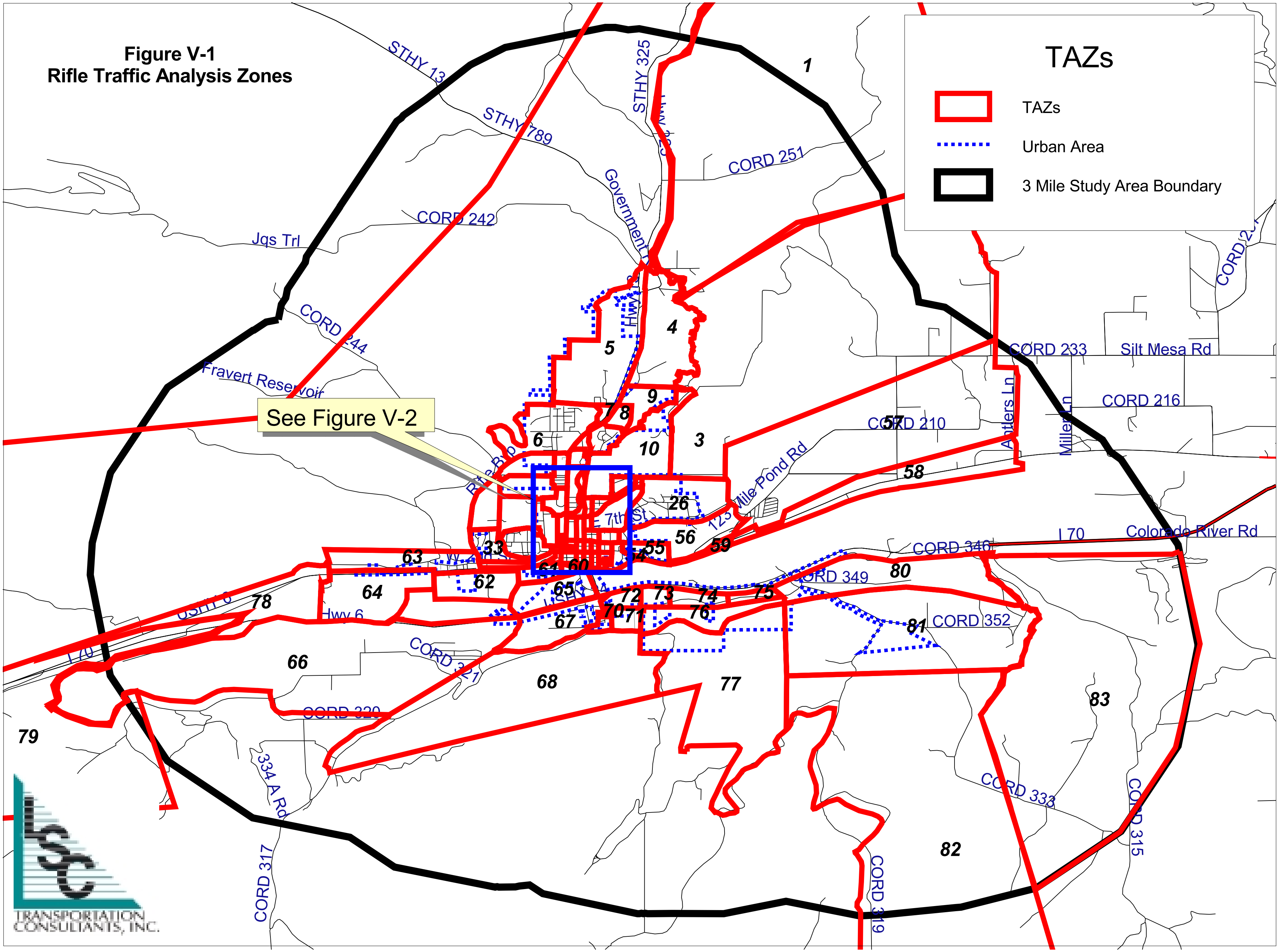
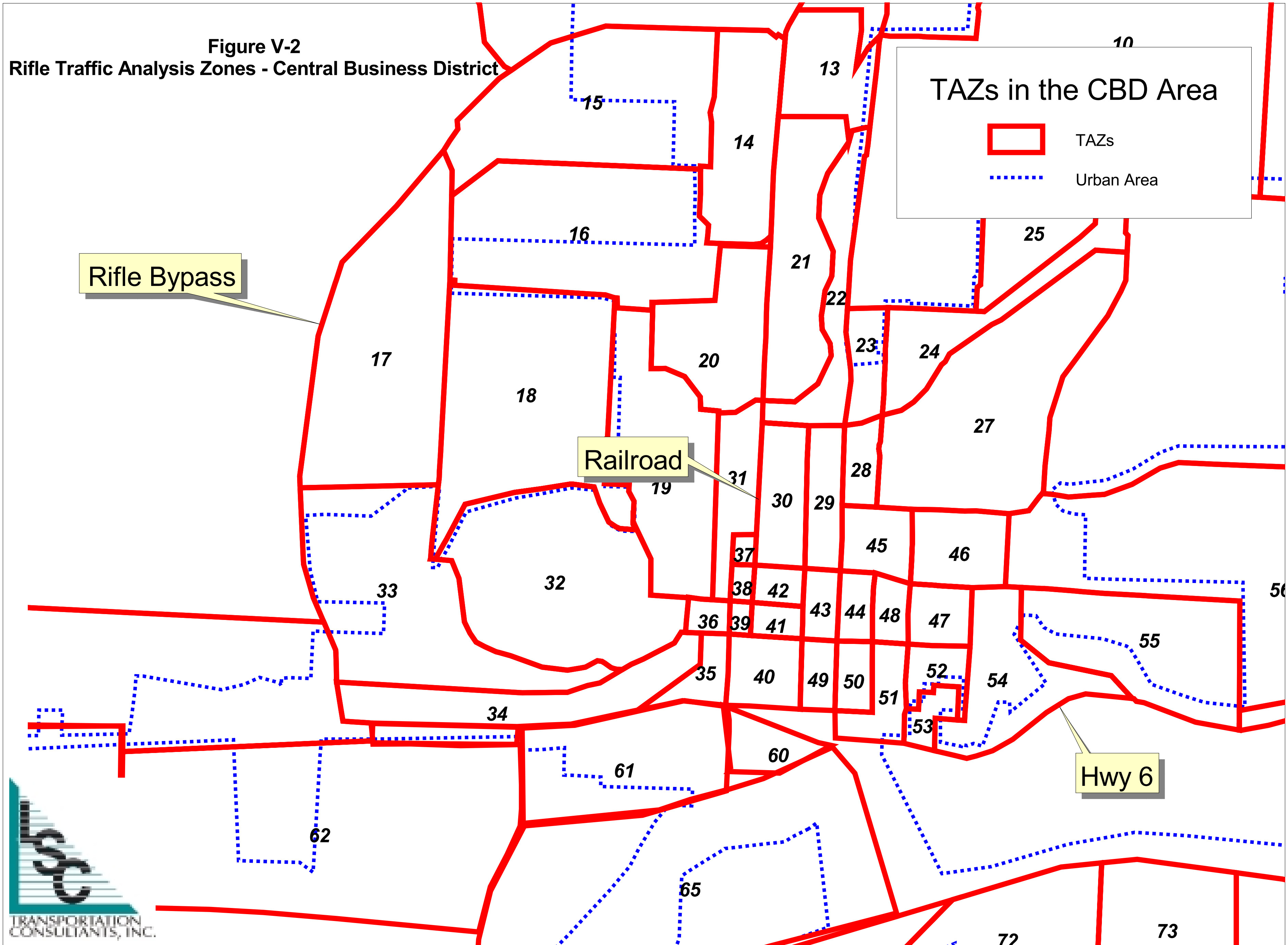


Figure V-2
Rifle Traffic Analysis Zones - Central Business District

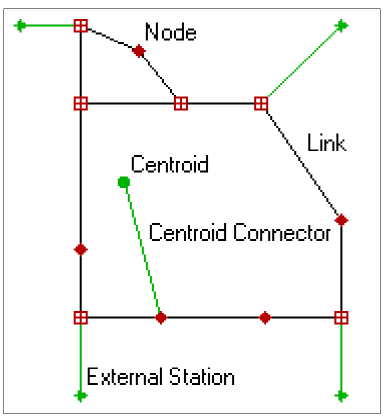


MODEL DEVELOPMENT

Rifle Model Development

A QRS II computer model has been developed for the Rifle study area based on the establishment of TAZs and the Rifle transportation network as described. Version 6.1 of QRS II was used along with General Network Editor Version 7.0 for data entry and analysis. The created network represents the existing land uses and the area roadway system. The street capacities, as well as free-flow travel speeds, were estimated for each street segment based on the functional classification of the road and speed limits. The model serves as a tool for forecasting future traffic volumes on the street system within Rifle. These volume projections represent traffic generated by the different land uses throughout Rifle.

Existing Street Network



In developing a transportation network model, the street system is represented by a series of nodes and links. This representation is an attempt to quantify the street system for use in a mathematical model. Inherent in the modeling effort is a simplification of the actual system of streets. Major roads and corridors are identified. Local residential streets typically are not included in the network because traffic volumes are related directly to the adjacent properties and do not create congestion problems. Travel on local streets within the TAZs cannot be represented in the model. Although this process is a simplification of the street system, it is possible to represent the system of arterial and collectors with a network and to replicate traffic flows on these principal streets.

The network is made up of a series of points and lines connecting these points. The points, or network nodes, represent the intersections within the street system. The line, or network links, represent the streets. Some impedance, or resistance to traffic flow, is associated with each of the links. There are special nodes within the network which are labeled zone centroids. These zone centroids are point representations of the TAZs. All traffic enters or leaves the network through these zone centroids. The network nodes are constrained so that all traffic entering the node on a link must also exit on a link.

External Stations

Many trips originate or terminate outside of Rifle. It would not be cost effective, practical, or necessary to represent all of the other communities and roads outside of the immediate Rifle study area. The alternative is to represent travel which originates or terminates outside of the study area by a single point where each of the major roads cross the study boundary. This model has four external points, one each at I-70 east, I-70 west, SH 13 north, and Highway 6 east.

The trips at external stations were estimated as part of the model calibration process and based on Colorado Department of Transportation data. The traffic volumes on the roads at the point represented by the external station were replicated in the modeling process.

MODEL LIMITATIONS

Although the model was developed using the latest techniques and best available information, there are limitations in the use of any model which is only representative of future real world conditions. One of the first limitations is that trip generation rates are assumed to be static. The rates which are valid for representing existing travel patterns are assumed to be valid for 20 or more years. In reality, travel patterns may change over time, and the amount of traffic could be higher or lower than reflected in the model results. Similarly, the use of different travel modes may also change, either increasing or decreasing the amount of private vehicular travel. This limitation can be overcome by updating estimates of future travel demand as new data become available.

The model does not reflect travel on local streets. All of the trips are loaded onto a network consisting of Collector streets, Arterials, and I-70. Local street intersections are not represented unless they could affect corridor delay calculations. As a result, the projected volumes on segments of Collector streets may be either high or low, depending on where the Collector street is loaded in the model. This limitation of the model has very little effect, if any, on Arterial streets. Care should be used in interpreting projections of traffic volumes on Collector or Local streets, such as using model volumes for site-specific traffic impact analyses.

HOUSING AND LAND USE

Introduction

Because it is impossible to explicitly know the travel characteristics of each individual in the population, it is necessary to develop relationships between travel demand and socioeconomic characteristics and land uses. Population and land use information for each TAZ are discussed further in Chapter VI. The "base year" is based upon the existing population and land use.

Housing

Travel volumes have been shown to be directly related to the number of dwelling units within the area of interest. The number of households in Rifle is based on 2000 Census data. Using a Geographic Information System (GIS), census blocks were either aggregated or manipulated in such a way to assign the appropriate estimate to the number of households in each of the TAZs for the base year model. Based on the 2000 data, and recent building permits issued in Rifle, the number of households was adjusted to reflect 2002 total households in Rifle. These were then assigned accordingly to each TAZ. This is discussed further in Chapter VI. The trip generation rates for dwelling units in Rifle are based on ITE established rates from *Trip Generation, 6th Edition.*

Commercial/Retail/Industrial

The number and location of businesses and jobs are also key determinants of travel activity. The existence of commercial, retail, and industrial land uses, as well as the type of business, in each zone is a factor which represents the attractiveness for travel between these zones. For purposes of the traffic model, it was necessary to identify the square feet of floor area by zone by several land use types (i.e., office, retail, storage, or general) as well as the number of trips generated by other unique land uses within each zone (i.e., schools, hospitals, lumber yards, etc.). In order to accomplish this task, staff at the Rifle Public Works Department searched current city property records to identify selected non-residential land uses. The Institute of Transportation Engineers (ITE) publication entitled *Trip Generation, 6th Edition* contains estimates of the number of trips generated by many different residential and non-residential land uses. One method of calculating the trip generation is by applying a rate to the known area (in square feet) of the building. Thus, the land use, number of square feet, and other pertinent property characteristics were identified, and correlated to parcel maps and aerial photography in order to identify the TAZ in which the property is located. The existing and projected land uses are discussed further in Chapter III.

TRAVEL DEMAND MODELING PROCESS

Trip Generation

Trip generation is the process of identifying relationships between human activities and travel characteristics. Human activities are generally represented by the character, intensity, and location of land uses. The purpose of trip generation is to determine the number of trips to and from the various geographic analysis areas within the bounds of the study.

In transportation planning, trips are usually defined as one-way, one-person movements either from an origin *or* to a destination. (Common usage of the term, trip, by contrast, typically implies a movement between an origin and a destination and may include more than one person if they are in the same vehicle.) A good example of transportation planning usage is the “home-to-work” trip. In trip generation, traveling from home to work involves *two* trip ends, one originating at home and the other terminating at work. For the Rifle model, trips were defined as vehicle-trips rather than person-trips. This is a simplified approach which allowed the use of trip generation rates from the Institute of Transportation Engineers publication *Trip Generation* which is a compilation of vehicle-trip rates for many different land uses. This approach also eliminates the need to estimate vehicle occupancy rates for individual trip purposes and mode splits for those same purposes.

The trip ends are usually referred to as productions and attractions. The definitions of productions and attractions depend somewhat upon the trip type being considered. For the Rifle network, four trip types were used:

(1) Home-Based Work (HBW)
(2) Home-Based Other (HBO)
(3) Non-Home-Based (NHB)
(4) External-External Trips (XX)

For home-based trips, the production end is always at the residence location. Therefore dwelling units create many trip productions. The other end of a home-based work trip is always an attraction. Places of employment “generate” trip attractions for home-based work trips. To restate, the production ends of home-to-work and work-to-home trips are both at the residence. The definition for home-based other trips (non-work trips with one end at home) is the same. In other words, for these trip types, origins and productions are *not* the same things. The residential end of the trip is always the production. The other end of the trip is always the attraction. In contrast, for non-home-based (NHB) and external-external (XX) trips, the trip productions are the same as origins and trip attractions are the same as destinations.

Trip Distribution

Trip distribution is the process of connecting the trip ends which have been generated for each of the analysis areas or TAZs. It is during this step that the linkage is made between all the productions and attractions of trips. Trip distribution is a significant element of the process because the trip interchanges must eventually be accommodated by the transportation system. The distribution of trips is essential to estimating the traffic volumes on individual links and determining a level of service.

The particular trip distribution model which is used in this analysis is a form of the Gravity Model. This model parallels Newton’s Law of Gravitation and is based on the assumption that all trips starting from a given area attracted to other areas are in direct proportion to the size of the attractor and in inverse proportion to the spatial separation between these areas. The spatial separation is measured in terms of the travel time between the two areas. The gravity model used in Rifle's QRS II model is based upon the exponential friction factor form.

Data for trip distribution include the coded network, the productions and attractions by trip purpose from trip generation, and the model parameters. Minimum travel time paths are computed for each of the possible origin and destination pairs. These travel times are then used to represent the spatial separation of the different origin and destination pairs.

The result of trip distribution is a trip table which indicates the number of productions for each analysis zone which is attracted by each zone. The production-attraction trip table is set up to produce trip origins and destinations for a full 24-hour period.

Friction factors are used to adjust the gravity model to account for the "attractiveness" of certain types of trips. In Rifle, for example, the friction factors work with the other gravity model parameters to indicate that longer trips are relatively less attractive than shorter trips.

Several possible choices existed for calibrating the distribution equation in this model. One option was to develop friction factors from "scratch." This approach would require a detailed household travel diary which is a very expensive process. A better approach was to estimate the factors based on the inverse of the average trip distance. By inputting the previous run's factors, a new set of factors is generated. By performing numerous iterations, final values are ultimately obtained, thereby indicating that the distribution equation is calibrated. This was the approach selected for Rifle.

Modal Split

Modal split (also known as mode choice) is the step in transportation modeling which estimates the portion of trips made using various modes which are available for travel. The available modes will vary by area and level of detail in the model, but may include drive-alone auto, shared-ride auto, local bus, express transit, rail transit, intercity bus, intercity rail, bicycle, and pedestrian.

Since Rifle has no local public transportation service, this was not an issue in the model. Rather than attempting to estimate any mode split, vehicle-trips were generated and this step was not included in the model.

Trip Assignment

Trip assignment is the process of allocating the distributed trips to specific links within the coded network. The assignment of trips to the network relies on the determination of routes through the network based on the impedance or travel time of each link.

Various assignment procedures exist depending on the type of estimate desired. Two widely used algorithms for trip assignment are the "all-or-nothing" assignment and the "capacity-restraint" assignment. The all-or-nothing algorithm assigns all of the trips to the shortest path, irrespective of the total volume of traffic on a particular link. For this reason, the all-or-nothing algorithm is considered to provide good estimates of "demand" for the various paths in the network where the supply of travel capacity (lanes) are unlimited.

The second algorithm, known as capacity-restraint, adjusts loading and travel times according to congestion. A portion of all trips are loaded. The model then evaluates changes to link speeds based on volume-to-capacity ratios, before loading another portion of the trips. Volume-travel time adjustments frequently follow the Bureau of Public Roads (BPR) equation as follows:

$$\text{Congested Travel Time} = \text{Free-flow Time} \times [(1+A)(V/C)^{B}]$$

where: A and B are constants (default values are 0.15 and 4.0, respectively) and V/C = volume-to-capacity ratio for previous iteration.

Factors which are adjusted in the second type of assignment process are the link free-flow speed and link delay function parameters. The result of the trip assignment step is a table of link volumes and related information such as volume-to-capacity ratio, operating speed, and travel time. The capacity-restraint loading is considered to provide an estimate of link volumes that are consistent with patterns observed through "ground counts." More about this subject is addressed in Appendix D, Network Model Calibration.